Machining

Working with Ti-5553: Optimizing Tool Life and Cutting Speeds

Kip Hanson | Sep 17, 2019

Learn the most important and challenging aspects of working with Ti-5553. This particular titanium material is not your average superalloy.

There are plenty of machine shops out there familiar with the Ti-6Al-4V type of titanium, and for the most part, they don't complain too much about machining it.

Ti-5553 is a completely different story.

With yield and tensile strengths nearly 50 percent greater than its more common relative, the titanium "beta" alloy Ti-5Al-5Mo-5V-3Cr is roughly 30 percent less machinable. This is a big deal for shops that make aerospace parts in abundance, because "triple nickel" use is on the rise.

What Is Ti-5553? Not Really Nickel, Cut Your Speeds in Half

William Durow, manager of the global engineering project office for customized solutions at ***Sandvik Coromant***, is quick to point out that the "triple nickel" moniker is a bit misleading.

Ti-5553 contains none of the nickel present in so many other superalloys.

It contains plenty of molybdenum, vanadium and chromium, which are elements that make "triple five three" strong and tough. They are a favorite for aircraft frame and landing gear components.

These elements, however, make Ti-5553 significantly more difficult to machine than its popular cousin.

"I suggest using cutting speeds at 50 percent of Ti-6Al-4V, so a good starting parameter would be 60 to 80 SFM (surface feet per minute)," says Durow. "An uncoated or PVD tool is the first choice, and it should have a sharp edge. We also recommend light cutter engagements, dynamic milling or similar trochoidal toolpaths, and as with most superalloys, cutting fluids are a necessity, with high-pressure coolant (HPC) a big plus."

Ti-5553: Common Tool Failure Modes and Edge Preparation for Better Tool Life

Michael Littlejohn, a senior applications specialist with GWS Tool Group, offers similar advice. He notes that beta alloy Ti-10V-2Fe-3Al is quite similar to Ti-5553, and if you're not prepared, can present the same level of machining trouble.

"Both are a little like cutting kryptonite," he laughs. "In fact, I've worked with several customers who found it necessary to index the cutting tool to a fresh edge after each pass. This was the only way to achieve predictable results and avoid scrapping what is probably a very expensive workpiece."

Whether cutting Ti-5553 or 10-2-3, tool failure modes are little different than with other titanium alloys. Both are relatively abrasive and generate extreme heat in the cutting zone, so the carbide should exhibit good hot hardness and crater resistance but be tough enough to withstand the higher than average cutting forces.

As Sandvik Coromant's Durow points out, a sharp-edged tool works best, but Littlejohn notes that a slight hone increases durability.

"Built-up edge (BUE) is also common and must be addressed immediately to avoid catastrophic tool failure," says Littlejohn.

"To shops that machine a lot of it, Ti-6Al-4V has almost become like cutting aluminum," adds Brian Hamil, vice president of product development at ***Kyocera SGS Precision Tools***. "To those who aren't used to it, however, Ti-5553 comes as a real surprise. Not only are the cutting speeds and tool life much lower, but you need to use a different machining strategy, one that relies heavily on chip thinning and lighter depths of cut in order to overcome the material's high strength."

Hamil also recommends edge preparation to protect the tool, maintain a sharp edge and provide maximum life.

Need a solution for burning through diamond-shaped cutting tools for lead angle work? Read "Optimizing Tool Life: The Effect of Lead Angles on Turning Operations."

The Value of Through-the-Tool Fluid Technology

Finding the right cutting tools, the right feeds and speeds and the right high-pressure cutting fluid is a critical first step when machining Ti-5553 and other beta phase titanium alloys, but even the most optimized process will fail if the tool is starved for coolant.

This is why cutting-tool manufacturers recommend using through-the-tool cutting fluid wherever possible, and why some—***Kennametal***, ***Sandvik Coromant***, ***Walter Tool***, and ***Iscar*** among them—offer tool holders equipped with "precision" coolant nozzles.

As the name implies, these direct cutting fluids where they're needed most, providing much-needed lubricity and helping with efficient chip formation. Most offer multiple plumbing options to address different machining conditions, and all reduce setup time and improve process stability.

Still using copper lines and plastic flex-hose? It may be time to get more precise.

Managing 'Alpha-Case' That Causes Cracking in Titanium

CNC machine operators should also manage tool life carefully, as dull cutters and overly aggressive machining parameters can generate enough heat to produce an oxidized layer known as alpha-case, a titanium-specific phenomenon that may lead to cracking and eventual component failure if not removed.

It's for this reason that machinists must adhere to customer-approved process plans and not change to a different brand or style of cutting tool—or even change feeds and speeds significantly—without first running those changes up the engineering flagpole.

With this constraint in mind, any shop new to beta titanium should set aside plenty of time for process development and cutting-tool selection upfront, as there will probably be few opportunities for changing either once the customer has signed off on the first article.

"If the process sheet says to change a tool at 10 pieces, then don't try for 15," says Jon Paggett, director of coating development at Kyocera Hardcoating Technologies, who also suggested using a heat-resistant but lubricious tool coating to help reduce the coefficient of friction.

You see a fair amount of Ti-5553 in today's landing gear in aircraft. Learn more about it in "Aerospace and Defense In Focus: Landing Gear Components."

Kennametal's Take on Ti-5553

According to Mark Francis, Aerospace and Defense Segment staff engineer for the solutions engineering Americas team at ***Kennametal***, this level of fine-tuning is a necessary part of any Ti-5553 machining strategy.

"You can't just use a general-purpose grade and attack it like you would other materials," he says. "If you really want to be successful with this and other beta titaniums, you need a carbide grade, geometry, coating and edge design that have been optimized for the specific alloy, together with the correct feeds, speeds and other process parameters. Then you need to adjust your expectations accordingly, because it simply doesn't cut like most materials."

That also means that your existing equipment might not be up to snuff. Francis recommends a very rigid machine tool and an equally rigid spindle interface for machining centers and live-tool lathes. He also suggests using the highest-pressure cutting fluid available to keep the work zone cool and blast chips out of the way.

"An adjustable orifice-size coolant nozzle technology can provide precise coolant delivery to the cutting zone to maximize heat dissipation," says Francis. "Let's not forget that titanium catches fire, so special attention should be paid to lubrication when machining it."

Finally, he says that customers shouldn't hesitate to ask for advice, even those who have experience with difficult metals.

"We've been working with Ti-5553 and other alloys of titanium for decades, most of it in the aerospace industry, and we always like to come on-site to work with customers on demanding applications like these," says Francis. "In one recent example, we reduced cycle time 30 percent by swapping out just one tool, which is saying quite a lot for this material."

Are you having issues with titanium? Ask our metalworking tech team any question or share your own expertise over on the forum.

